Effect of the shape of superabsorbent polymers on the self-healing aspects in cementitious materials

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Autogenous healing is one of the promising paths to counteract the formation of cracks in concrete. A way of promoting this autogenous healing is by limiting the cracks by means of synthetic (polyvinyl alcohol) microfibres and by providing the necessary water by means of superabsorbent polymers (SAPs) [1-3]. There are different types and sizes of SAPs which will influence the fresh and hardened properties of the cementitious material, i.e. the microstructural and the self-healing properties. Different SAPs, ranging from irregular bulk types over fibres and perfect smooth spherical particles to grape structures and collapsed particles (Figure 1), were studied as an additive (0.5 and 1 mass percent [m%] of cement weight). Mortar specimens were made, were cracked by four-point-bending at an age of 28 days and were healed in wet/dry cycling (1 h in water and 23 h at a relative humidity equal to 60%) for 28 days. Afterwards, they were retested under four-point-bending to study the regain in mechanical properties.

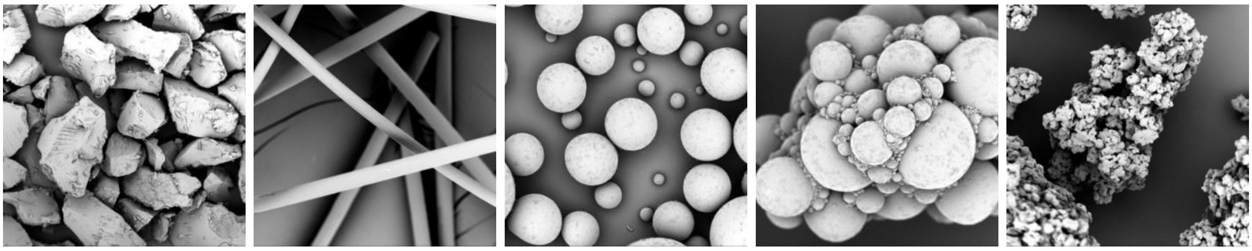

Figure 1: Different types of studied SAPs. The figures are 400 µm wide (×600).

As SAPs absorb part of the mixing water, they affect the macro pore distribution as they remain as water-filled inclusions when the cementitious material is hardening. These macro pores affect the mechanical strength of the overall material. The amount of absorbed mixing water seems to be dependent on the size of the particles. As smaller particles have a higher surface area available for absorption of mixing water, their mixing water absorption value is higher. A small round shape of the particle obstructed the workability less compared to an irregular particle with the same size. A fibre type did show an influence due to a balling effect, obstructing the handling.

The regain in strength is comparable for all mixtures (Table 1). One needs to bear in mind that the regain is determined based on the initial strength of the material. Two criteria for optimal self-healing need to be met. These are no reduction in strength and optimal autogenous healing and regain in mechanical properties. Therefore, a new parameter *HE* (Healing Efficiency) was proposed, being the relation between the strength and the reference strength multiplied by the regain in mechanical properties.

Table 1: Mixing water, first-cracking-strength and regain in mechanical properties.

Type of SAP & size	Mixing water absorbed [g/g SAP]	m%	First-cracking-strength σ_{fc} [MPa]	Regain in σ_{fc} (wet/dry) [%]	Healing efficiency *HE* [-]
REF without SAPs			5.5 ± 0.6	46 ± 7	
Bulk 100 ± 22 µm	30.5	0.5	5.4 ± 0.8	60 ± 6	0.59
		1	3.1 ± 0.8	77 ± 6	0.43
Bulk 477 ± 53 µm	8.9	0.5	5.6 ± 0.7	73 ± 5	0.74
		1	5.3 ± 0.5	87 ± 8	0.84
Fibre 5.2 mm ℓ * ø27 µm	32	0.5	4.7 ± 0.5	63 ± 9	0.54
Spherical 70 ± 34 µm	~0	0.5	5.2 ± 0.6	69 ± 3	0.65
		1	4.9 ± 0.5	66 ± 8	0.59
Grape 492 ± 79 µm	16	0.5	5.5 ± 0.7	65 ± 7	0.55
		1	5.4 ± 0.8	58 ± 5	0.57
Collapsed 165 ± 32 µm	16	0.5	5.4 ± 0.8	47 ± 7	0.46
		1	5.0 ± 0.8	64 ± 3	0.58

In wet/dry cycles, the reference showed healing of approximately 45% of the first-cracking-strength. Mixtures with SAPs showed typically 60-90% regain in mechanical properties when stored in wet/dry cycles. SAPs thus promote autogenous healing. The best overall mixture in this study is obtained when using bulk SAPs with a size of approximately 500 µm. The strength is hereby not reduced significantly and the regain in mechanical properties is optimal. This led to a good value for *HE* (0.84).

References

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